Manufacturer	Typical: 64 - QAM	SCS' BCDMA
Freq Band (GHz) Capacity	1.85-1.99 DS-3	1.85-1.99 28+2 DS1s
RF Bandwidth Modulation	10 64 QAM	48 B-CDMA
TX Power (dBm) Threshold, FCE (dBm) System Gain (dB)	30 -72 100	30 -82[1] 112
Freq Source IF Freq	SYN 70 MHz	Fixed Xtal 70 MHz
Equalizer	YES	NO
Linear Power Amplifier	YES	NO

TABLE 1.2 COMPARISON OF MICROWAVE SYSTEMS

[1] For BER = 10^{-6}; theoretical limit is -91 dbm, threshold to achieve BER = 10^{-3} is -85 dbm.

4.0 Summary

In this section, SCS has demonstrated that the use of B-CDMA will allow fixed microwave users to share the band with PCS users without fearing excessive interference. In addition, B-CDMA will allow fixed microwave users to increase their number to 10 fixed users/square mile.

Micro cellular propagation at 1850 MHz and 900 MHz

Prepared by LCC incorporated on behalf of CTIA
October 23, 1992

Table Of Contents

I Introduction

The FCC recently allocated a portion of the 1850 MHz band for a new type of communication concept termed PCS (Personal Communication System). This new frequency band is being made available in the midst of various emerging technologies that may be capable of providing a variety of services that are not currently provided through conventional cellular. If 1850 MHz band-width is allocated to only new carriers the FCC may be treating existing cellular carriers unfairly. If 1850 MHz is uniquely suited to certain services or is easier to engineer under certain conditions, then current 900 MHz licensees may be disadvantaged in the next few years as new services are offered by PCS licensees at the new frequency.

Various types of tests have been performed at these two frequencies, both macro cellular and micro cellular. Transmitters have been placed on top of buildings and in-building as well as on-street measurements performed to see the relative building penetration at these two frequencies. Macro cellular measurements (cell radii in the order of 2-7 miles) have been made to study and compare the channel statistics for these two frequencies. However, one scenario that has not been tested adequately is when the transmitter is placed within the building and measurements performed at both frequencies simultaneously with the receiver both inside the building and outside the building.

By placing an 1850 MHz and 900 MHz transmitter in the same room of a building and simultaneously measuring received signal strength on the street as well as inside the building we hope to make effective conclusions regarding the relative difference in signal strength between two frequencies in a micro-cellular environment. If the received signal strength on the street at 1850 MHz proves to be weaker than 900 MHz, then it would appear that an 1850 MHz micro-cell would create less interference with another cell at the same frequency in the vicinity.

II Measurements

Measurements were performed with the following transmitter and receiver locations:

Transmitter	**Receiver**
9th floor LCC	8th,9th,10th and on-street around building
4th floor TSI	On-street around building

Two transmitters- one at 900 MHz and one at 1850 MHz- were placed in the same room for each test. There was a seven foot separation between the two transmitters to avoid coupling between the antennas. The receiver, which consisted of a modified Cellumate, collected signal strength data at both frequencies simultaneously and stored it in a laptop computer for future processing. The in-building measurements were carried out on a cart wheeled around to various locations on each floor while the street level measurements were done using an LCC van.

III Theoretical Background

According to the free space path loss formula their should be a uniform difference in signal strength between the two measured frequencies (see equation below). Theoretically the signal strength at 879.99 MHz should be stronger than at 1850.21 MHz. Of course the environmental clutter in the mobile path will tend to bias the difference.

$L_f = 32.5 + 20 \text{ Log} d + 20 \text{ Log } f$ [1]

L_f= Path loss in dB
d=Distance in Km between transmitter and receiver
f=Frequency in MHz.

$L_{1850.21 \text{ MHz}, d \text{ Km}} = 32.5 + 20 \text{ Log } d + 20 \log 1850.21 = 97.84 + 20 \text{ Log } d$

$L_{879.99 \text{ MHz}, d \text{ Km}} = 32.5 + 20 \text{ Log } d + 20 \text{ Log } 879.99 = 91.39 + 20 \text{ Log } d$

Therefore, the free space path loss difference at any distance d is given by $L_{1850.21} - L_{879.99} = 6.46$ dB.

This difference in received signal level is due to the fact that the effective aperture of the antenna at 1850.21 MHz is smaller due to the smaller wavelength

$(A_{eff} = \frac{\lambda^2}{4\pi})$. [2]

Previous in-building measurements have demonstrated that building penetration loss is consistently *less* at 1850 MHz than at 880 MHz. Which means that although PCS frequencies exhibit more free space loss due to the reduced effective antenna aperture, the higher building penetration loss at 900 MHz may serve as a compensatory mechanism. However, these conclusions were based on transmitters placed outside and usually on rooftops. In the current measurements the transmitters were placed inside the building; therefore, free space conditions were never present. Since the antennas in this experiment were surrounded by walls and glass the relative building penetration loss for the two frequencies was always a factor. But since the angle of reception constantly changes relative to both transmitters the difference in signal strength also varies as a function of the blocking in the transmission path. Macro cellular measurements in the past have shown that the local environmental clutter in the vicinity of the receiver tends to increase the difference in received signal strength to approximately 10 dB (favouring 900 MHz). In this case there is clutter surrounding both the transmitter and receiver which may impose a different bias on the received signal levels. The results discussed in section VI reflects some of these considerations.

IV Test Area and Procedure

All measurements were performed in or around the LCC office in Arlington. The areas that were driven are characterized by 2 to 14 storey buildings spaced fairly wide apart. Several streets crisscrossing the area were driven until the signal strength became very weak (less than -110 dBm). Please note the enclosed map which shows specific routes that were driven as well as associated markers. Almost identical routes were driven for both transmitter locations so that meaningful correlations could be established.

In-building test procedure

Before the following steps were taken the cellumate was used to determine if any signal was detectable at the two frequencies with the transmitters turned off to prevent interference from unwanted sources. Planned measurements were made only after it was determined that no other sources were present.

1. The receive equipment was first calibrated using a signal generator with a set of known input signals at both frequencies.

2. Transmit antennas were placed at least 7 feet apart. Receive antennas were placed as far apart as physically possible on the cart.

3. The modified cellumate was placed in a cart and wheeled to various locations inside the building on each floor.

4. Location information was catalogued by noting particular marker numbers on associated floor plans as well as on the data file as measurements were made.

5. Collected data was continually stored on floppy disk for post-processing.

6. The output ERP was occasionally checked for equal ERP at each frequency.

Street Level Measurements Procedure

1. The Cellumate was placed inside a van and driven in various directions from the transmitter location until the signal strength fell below -110 dBm.

Marker Number Information

A) Transmitters at LCC 9th floor in room 919.

i) Markers 100-137 correspond to the 10th floor.

ii) Markers 899-937 correspond to the 9th floor.

iii) Markers 800-851 correspond to the 8th floor.

iv) Markers 500-564 correspond to Streets.

B) Transmitters at TSI Building 4th floor in room.

i) Markers 600-644 correspond to Streets.

Note: No in-building measurements were made for TSI building.

V Equipment setup

<u>Transmitter setup</u>

1850 MHz

The same transmitter was used for all site locations. The transmitter RF output was an 1850.21 MHz carrier wave with approximately 5 watt ERP. (Effective Radiated Power). The carrier was produced by a Fluke 6062A signal generator, amplified by a Tron-tech 40 dB amplifier, band-pass filtered by a K & L tunable filter and fed to a Til-Tek 10 dB omni-directional antenna.

900 MHz

The 900 MHz transmitter consists of a Plexsys transmitter filtered using the K & L tunable filter connected to a 10 dB gain dB 806 omni-directional antenna. The input to each antenna was calibrated to the same ERP using a Bird watt-meter.

Both transmitters were placed inside the same room looking through windows along at least one street.

VI Data format and Post-Processing

The collected data was post-processed using CMA version 3.3 in conjunction with Microsoft Excel (version 3.0) for windows.

The following notation and definition have been used in processing the data .

1. Average Signal Strength(dBm) $x=\sum_{i=1}^{N} x_i /N$

where x_i is the individual measurement and N are the number of measurements at a marker location.

2. Signal Strength Difference (dBm)=(S.Strength at 900 MHz)-(S. Strength at 1850 MHz).

3. Standard Deviation (dBm) $\sigma=\sqrt{\frac{1}{(N-1)}\sum_{i=1}^{N}(x_i - x)^2}$

4. The average road and in-building signal strength value represents a single average of all measurements made in that area. Similarly values of standard deviation were obtained as shown in table 1 and 2.

5. Floor plans and maps are provided in the appendix have marker numbers associated with the individual locations where the measurements were taken. Each marker number consists of 100s of measurements. All the data files marked *.dat (each data file has been named according to the first marker number of that particular location) contain all the collected data.

VII Graphs

1. The 2-D Graphs are based on all marker numbers shown in the floor plan and the street maps attached in the appendix. Charts 1.1, 2.1, 3.1, 4.1 show the variation of signal strength across the 9th, 8th, 10th floor of LCC office, Wilson and Clarendon Blvd.. (road) both at 900 and 1850 MHz. Chart 1.2 .2.2, 3.2, 4.2 show the difference in signal strength of 900/1850 MHz at the same locations on the 9th, 8th,10th floor and Wilson Blvd.. Signal Strength Difference (dBm)=(SS at 900 MHz)-(SS at 1850 MHz). For these set of measurements both 900/1850 MHz transmitters were located at LCC 9th Floor in room 919 (see floor plans of 9th floor).

2. Second set of measurements were taken along Wilson and Clarendon Blvd.. roads with the transmitters set inside 4th floor of TSI Building. Chart numbering for this data set is consistent with the previous set mentioned above.

3. Charts 4.3, 4.5, 5.3, 5.5 show signal strength both at 900 and 1850 MHz along 2 strips which were driven along Wilson Blvd. and Clarendon Blvd.. road (moving away from the transmitter). Charts 4.4 4.6, 5.4, 5.6 show the difference in signal strength measurements of the above graphs respectively.

4. Charts A shows a comparison of the signal strength difference between 8th, 9th, 10th floor at LCC office.

5. Similar to chart A ,graph B shows the signal strength difference on the same route when the transmitters are at two different locations.

VIII Results and Conclusions

Based on the measurements presented in these experiments:

1. The average difference in signal strength between 900 MHz and 1850 MHz is more inside the building than outside. Inside the building the difference ranges from 5.63 to 13.56 dB while on street it is 3-6 dB. In other words a micro cell at 900 MHz placed in-building will provide better in-building coverage than one at 1850 MHz provided the ERPs are equal. The increased difference in SS between 1850 and 900 MHz [900MHz higher] indicates that 1850 MHz offers good isolation between cells within the building. This becomes an asset as new PCS services increase demand and require cells within a building to reuse.

2. While 900 MHz will provide better coverage in-building, it will also tend to be an intereferer with respect to an 1850 MHz antenna since it exhibits higher on-street signal levels (that would have also been the case for a cell placed on a roof top). Interestingly, it appears that the average difference between 900 MHz and 1850 MHz on the street is either approximately equal to or less than the free space path loss difference of 6.46 dB. This negative bias may be due to the possibility that the 1850 MHz carrier is not attenuated as much as the 900 MHz carrier as the building walls are penetrated (this is consistent with measurements made by Bell labs and the University of Liverpool[3]). Note that it is almost impossible to ensure identical paths for the two transmitters due to the nature of the test and the variation in the immediate reflectors surrounding the two transmitters (averaging is the only way to smooth out these variations).

3. In a limited number of instances the 1850 MHz carrier is stronger than the 900 MHz carrier. As mentioned in the previous paragraph this is probably due to the difference in the transmitters' immediate reflectors.

4. When the transmitters are in the 9th floor in room 919 then from chart1.1, 1.2 and the floor plans of 9th floor it can be concluded that signal strength remains almost constant (-30 dB for 900 MHz , -40 dB for 1850 MHz) for markers (910-917) directly in line of sight. For these marker locations the difference in SS for 900/1850 MHz is approximately constant and follows free space path loss formula. For markers which are partial in or out of LOS the SS strength at both frequencies decays very rapidly and the difference in SS decreases and it no longer has log f dependence. Here multipath reflections, diffraction, scattering, penetration loss become a dominant part in determining SS difference between the two frequencies.

5. Charts 4.3, 4.5, 5.3, 5.5 show signal strength for marker locations moving away from the transmitter. . In these plots at some instances 1850 MHz carrier becomes stronger than 900 MHz carrier. This mostly occurs when the receiver is at large distances from the transmitter.But since we do not have enough marker locations far away from the transmitter no definite conclusions can be made at this point

IX Notes

1. William C.Y. Lee " Mobile Communications Engineering " , (McGraw-Hill Book Company ,1982), p.189.

2.William C.Y. Lee "Mobile Cellular Telecommunication Systems", (McGraw-Hill Book Company ,1989), p.148.

3. A. F. de Toledo, A. M. D. Turkmani "Propagation into and within buildings at 900, 1850, 2300 MHz ",1992 IEEE, p. 633-636.

X Bibliography

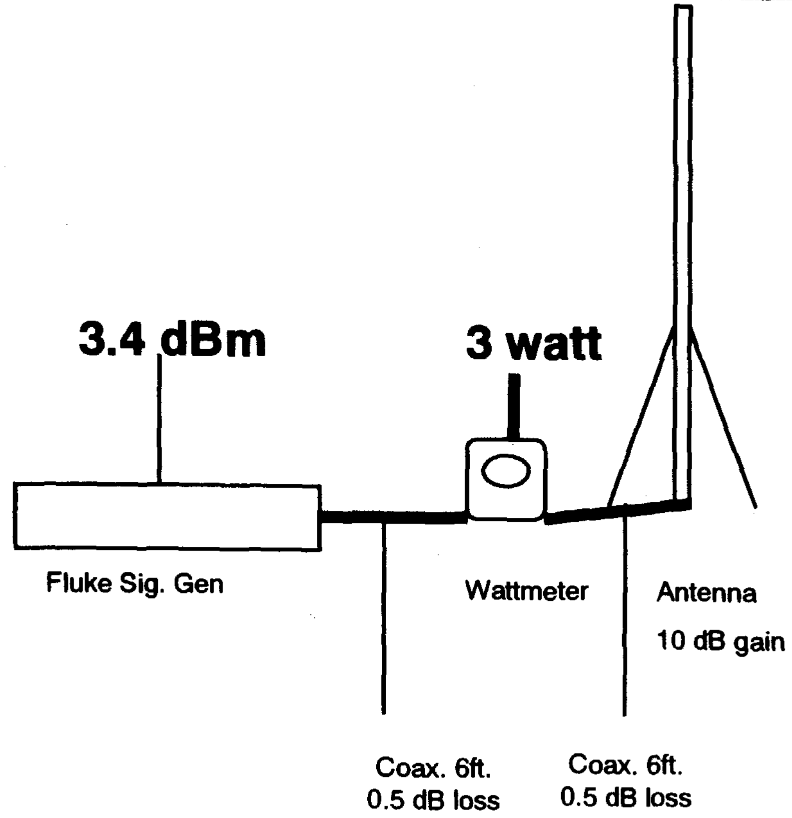
1. William C.Y. Lee " Mobile Communications Engineering " , (McGraw-Hill Book Company ,1982)

2.William C.Y. Lee "Mobile Cellular Telecommunication Systems", (McGraw-Hill Book Company ,1989)

3. A. F. de Toledo, A. M. D. Turkmani "Propagation into and within buildings at 900, 1800, 2300 MHz ", 1992 IEEE

Appendix

Block Diagram Of Transmitter At 900 MHZ



Block Diagram Of Transmitter At 1850 MHZ

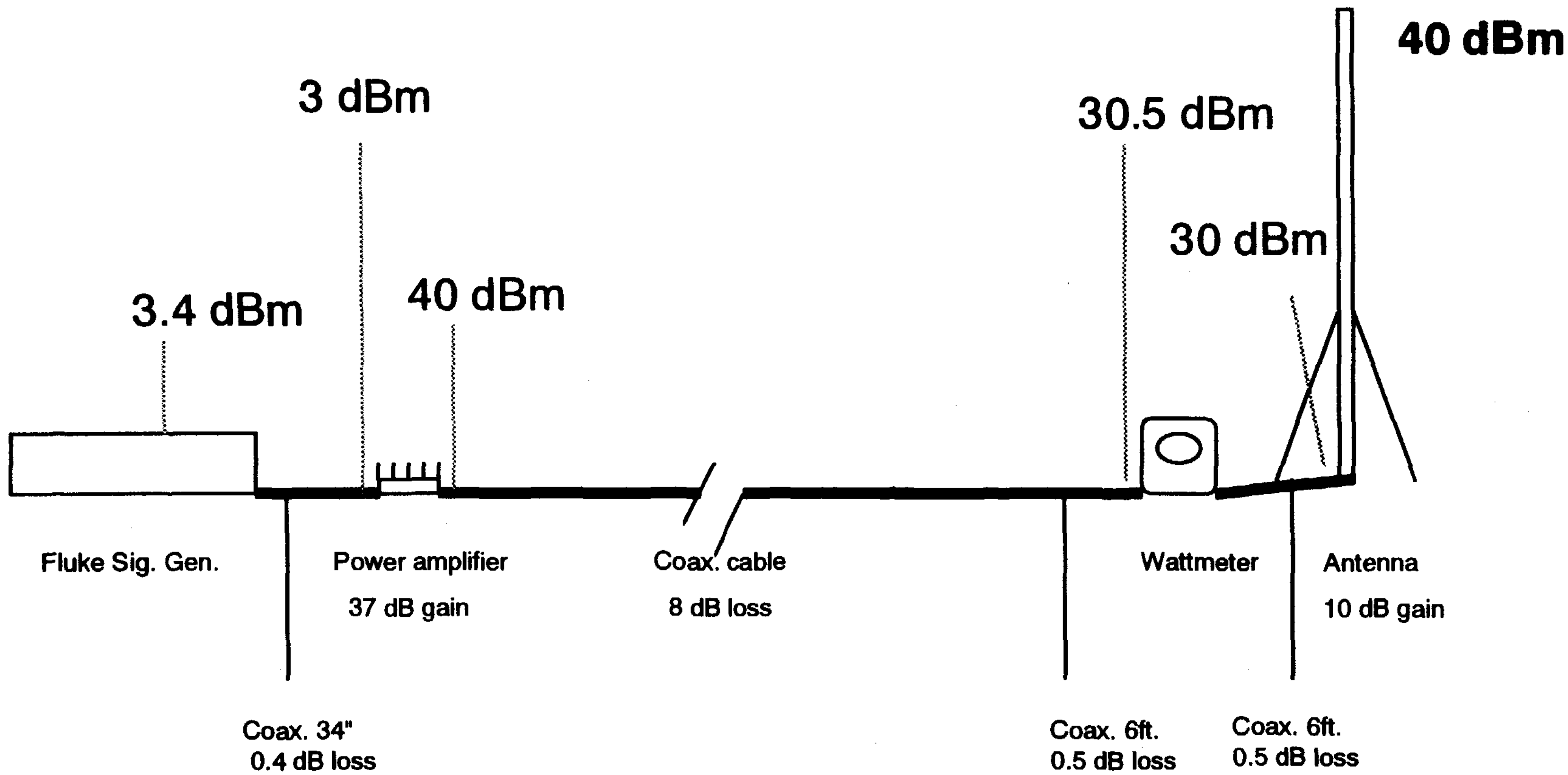


TABLE 1

Transmitter at LCC 9TH FLOOR RC=115 FT ERP=3W						
		Difference Avg	Frequency= 1850 MHZ		Frequency= 900 MHZ	
Location	Structure	(900-1850)MHZ	Average	Stdev	Average	Stdev
	Type	(dB)	(dB)	(dB)	(dB)	(dB)
On Street	on road	3.49	-85.40	15.89	-81.91	20.00
LCC 8th Floor	glass/wood/concrete	5.63	-73.35	16.13	-67.72	19.52
LCC 9th Floor	glass/wood/concrete	6.28	-59.84	14.95	-53.56	17.20
LCC 10th Floor	glass/wood/concrete	13.56	-79.20	13.08	-65.64	17.37

TRANSMITTER AT LCC 9TH FLOOR

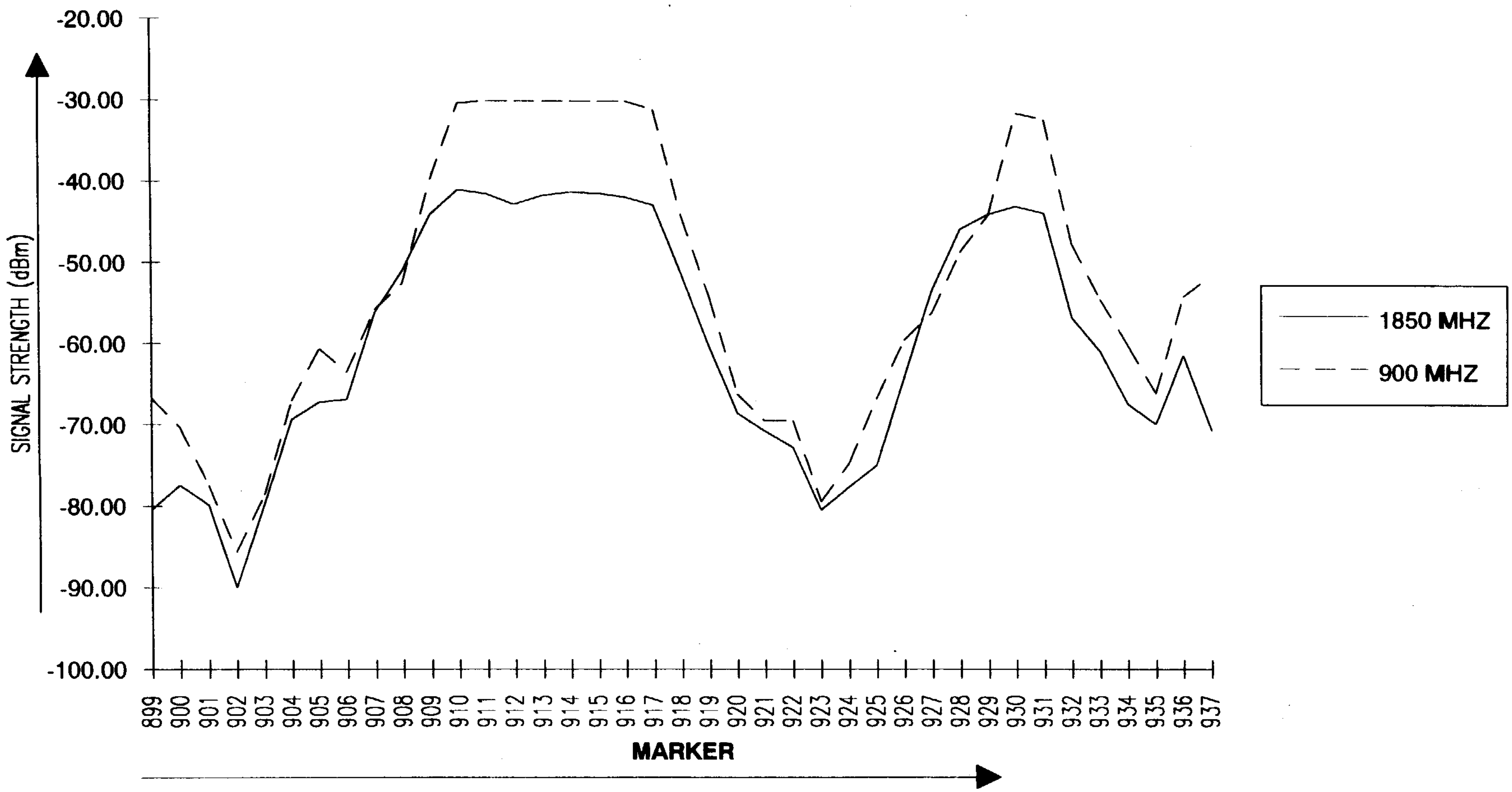
TABLE 2

Transmitter at TSI Building 4TH FLOOR RC= FT ERP=3W						
		Difference Avg	Frequency= 1850 MHZ		Frequency= 900 MHZ	
Location	Structure	(900-1850)MHZ	Average	Stdev	Average	Stdev
	Type	(dB)	(dB)	(dB)	(dB)	(dB)
On Street	on road	5.94	-77.78	17.05	-71.84	21.17

TRANSMITTER AT TSI BUILDING 4TH FLOOR

CHART 1.1

SIGNAL STRENGTH AT LCC 9TH FLOOR AT 900/1850 MHZ



TRANSMITTER AT LCC 9TH FLOOR

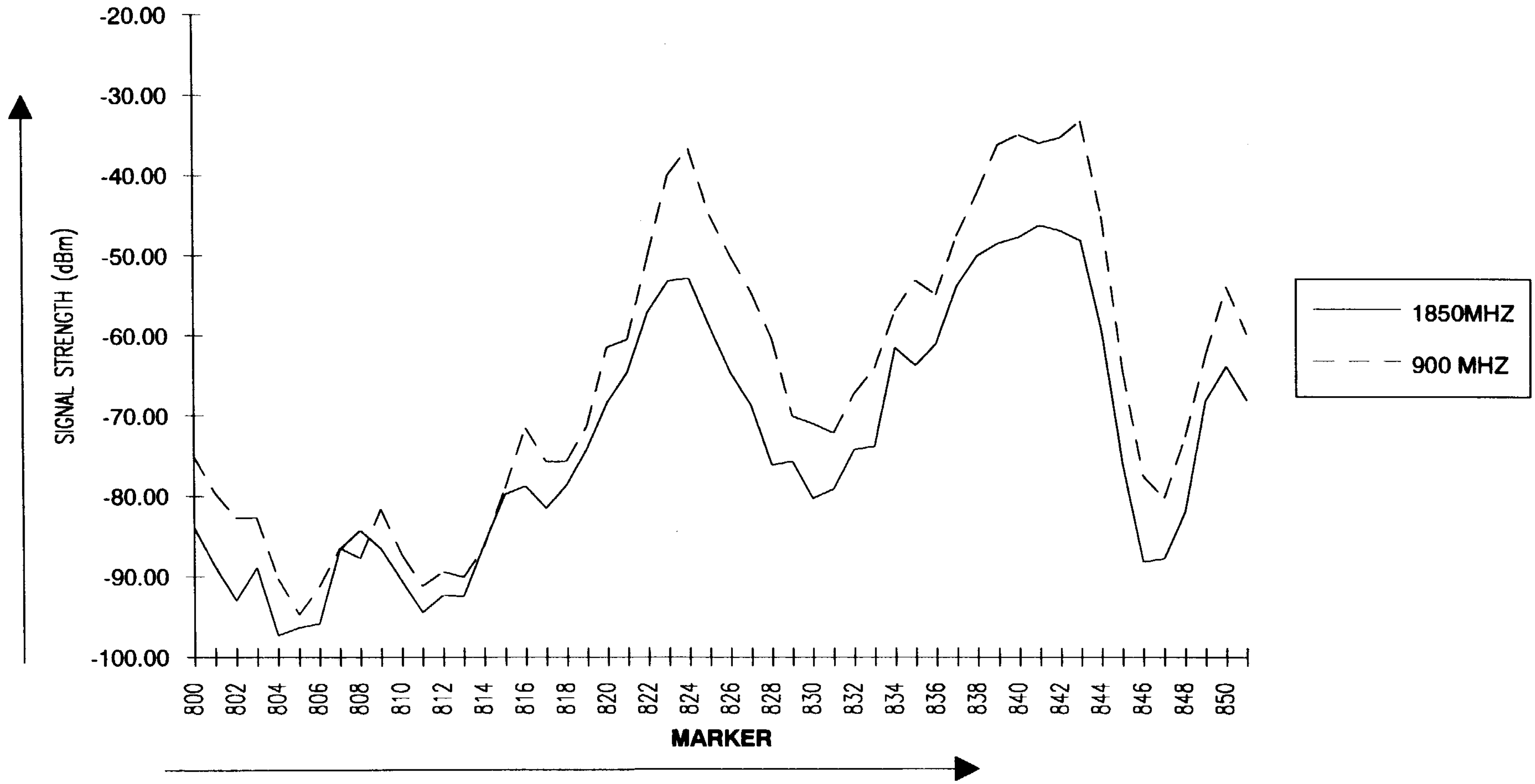
CHART 1.2

DIFFERENCE IN SIGNAL STRENGTH AT 900 AND 1850 MHZ AT LCC 9TH FLOOR

TRANSMITTER AT LCC 9TH FLOOR

CHART 2.1

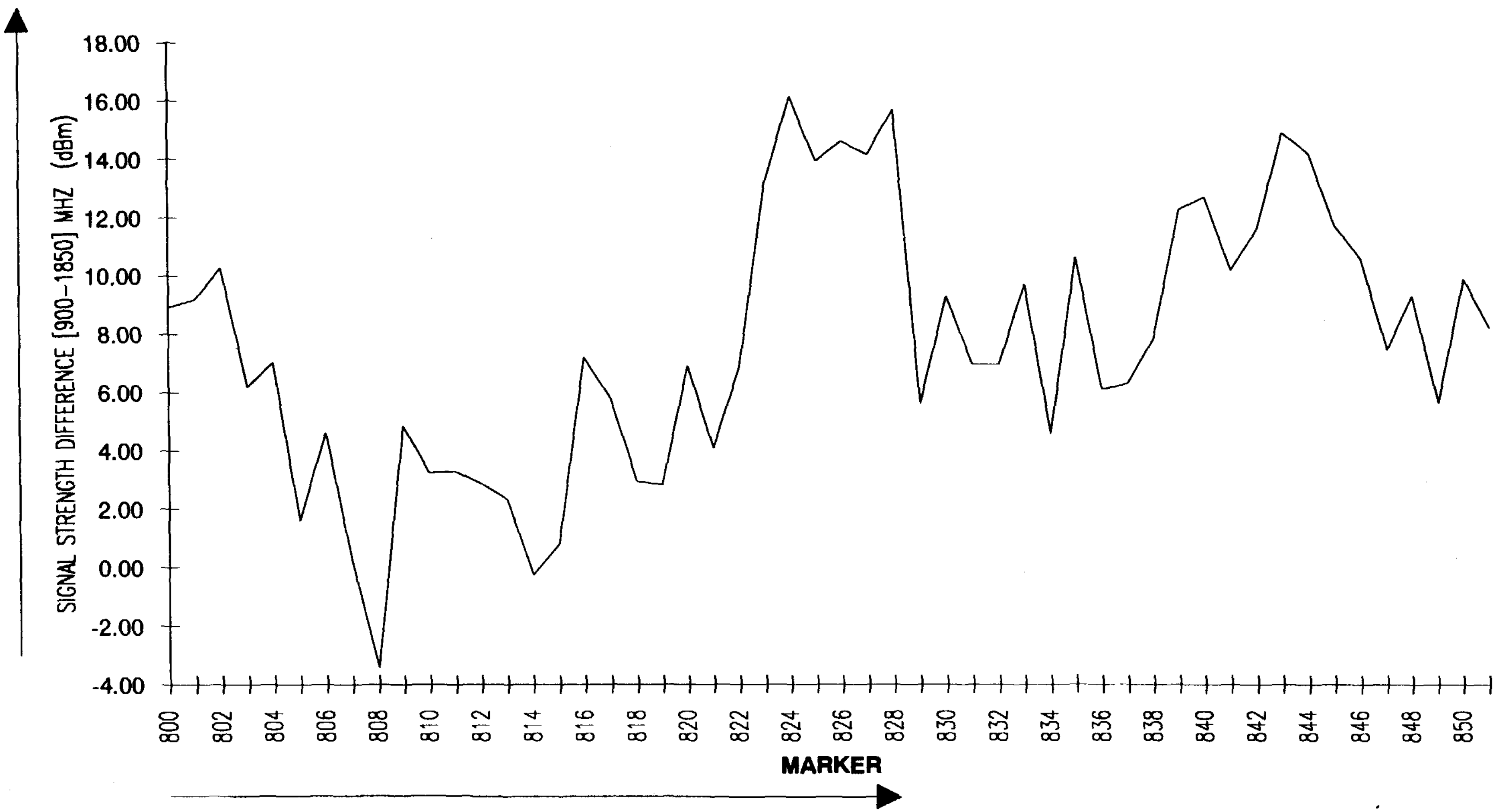
SIGNAL STRENGTH AT 900 & 1850 MHZ AT 8TH FLOOR



TRANSMITTER AT LCC 9TH FLOOR

CHART 2.2

DIFFERENCE IN SIGNAL STRENGTH AT 900 & 1850 MHZ AT 8TH FLOOR



TRANSMITTER AT LCC 9TH FLOOR